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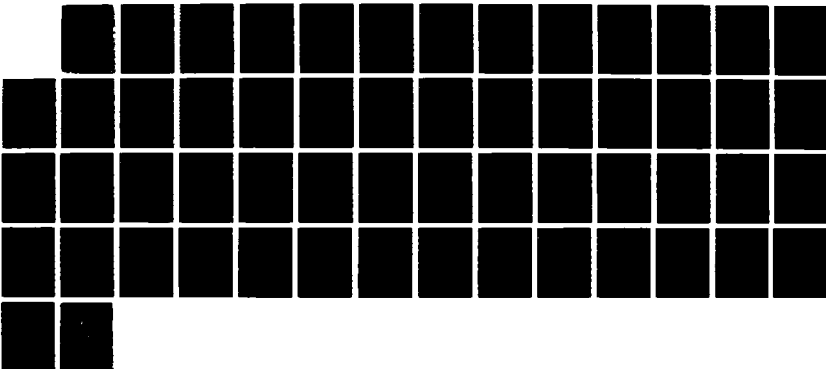
A YEAR OF PROGRAMMING(U) TEXAS UNIV AT AUSTIN DEPT OF
COMPUTER SCIENCES J C BROWNE ET AL. 1967
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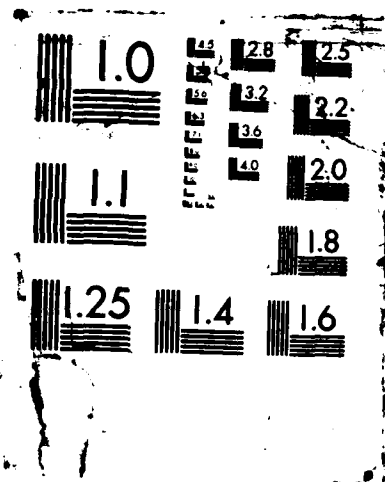
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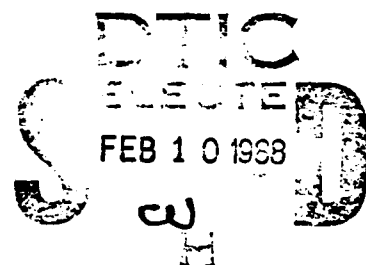
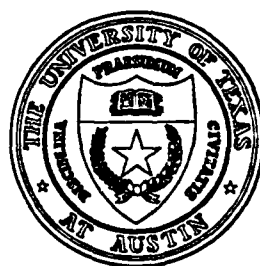
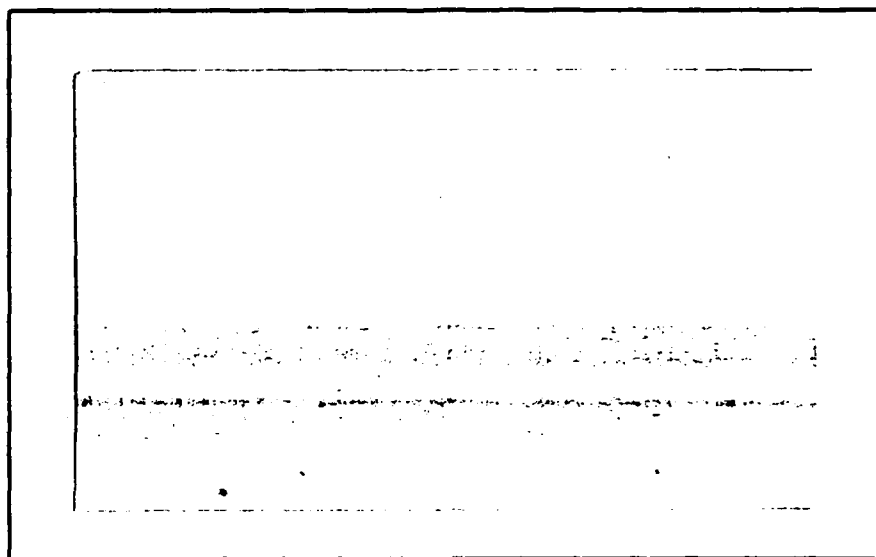




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DEPARTMENT OF COMPUTER SCIENCES
THE UNIVERSITY OF TEXAS AT AUSTIN

AUSTIN, TEXAS 78712

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**FINAL
TECHNICAL REPORT
1986-87**

A Year of Programming

Contract ONR N00014-86-K-0466

The University of Texas at Austin
Department of Computer Sciences
Taylor Hall 2.124
Austin, Texas 78712-1188

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DISTRIBUTION STATEMENT A

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A Year of Programming

Contractor: Department of the Navy

Contract Number: N00014-86-K-0466

Contract Amount: \$99,837*

Effective Date of Contract: July 1, 1986

Expiration Date of Contract: September 30, 1987

Co-principal Investigators: James C. Browne and Jayadev Misra
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Personnel:

Hamilton Richards, Coordinator
Suzanne Kain Rhoads, Senior Administrative Associate
Temporary clerical staff:
B. Burson, Renate Dyke, R. Loyless

Expenditures 7/1/86-9/30/87:

Salaries and Wages	\$44,713.64
Fringe Benefits	9,653.68
Other Expenses	5,171.42
Consultants	6,879.95
Consultants Travel	2,912.31
Overhead	30,506.00
Total	\$99,837.00



*The Year of Programming activities were augmented with funds from ONR N00014-86-K-0763 in the amount of \$488,038.

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YEAR OF PROGRAMMING

The 1987 University of Texas Year of Programming was established early in 1986, in response to a proposal by Profs. J. C. Browne and J. Misra, with the following goals:

- 1) to advance the art and science of programming by bringing leading scientists together for discussions and collaboration;
- 2) to disseminate among leading practitioners the best of what has been learned about the theory and practice of programming; *arr 2*
- 3) to provide critical research direction for the University Research Initiative in Formulation and Programming of Parallel and Distributed Computation. *see p 2*

Upon acceptance of the proposal by the Office of Naval Research, a Year of Programming management committee was established, consisting of a dozen members of UT's Computer Sciences faculty and one representative each from MCC and Lockheed/Austin. A half-time coordinator (H. Richards) was appointed in August, but the half-time administrative associate (S. K. Rhoads) did not join the YoP office until November.

When the management committee proved too cumbersome for the frequent and intensive consultations which the early planning stages required, an executive subcommittee was formed, consisting of J. C. Browne, E. W. Dijkstra, C. A. R. Hoare, and H. Richards. Out of the executive subcommittee's weekly meetings came the decision that the Year of Programming's major effort would be a series of Programming Institutes, each composed of some combination of research seminars, tutorials, and workshops, whose influence would be extended beyond their immediate audience through the distribution of published proceedings and videotapes.

Accomplishments

The Year of Programming's goals have been substantially achieved by its accomplishments during 1986-87, which included a workshop and five Programming Institutes (described individually below), each devoted to a topic at computing's scientific frontier. Each institute was presented by six to a dozen or more of the leading scientists in its subject area, and drew an audience from industry, government, and academia numbering between 75 and 106 (except for one institute, which was limited by the availability of suitable computing equipment to 30).

These events have effectively brought into focus the state of knowledge concerning formal aspects of programming, have propagated that knowledge to a large, diverse, and influential audience from universities, industry, and government, and have stimulated critical evaluation

of research directions for the URI in Formulation and Programming of Parallel and Distributed Computation at The University of Texas. The coordinated proceedings and videotapes of the Institutes provide an opportunity for further dissemination of this important body of knowledge (see Plans for next year's work, *infra*).

Workshop

0. **Real-Time Systems Workshop (24-25 November)**
Director: Prof. A. K. Mok (UT Austin)

A small-scale workshop, involving about two dozen participants, met on the UT campus to bring together academic researchers and builders of real-time systems to enable researchers to assess their work's potential impact and to enable system builders to learn about current research and to influence its direction to advance the design of real-time systems. The workshop disclosed that there is a serious lack of communication between researchers and practitioners, but that recent advances in specification methodology, temporal logic, and scheduling theory may provide a theoretical groundwork for real-time-system design.

Programming Institutes

1. **Concurrent Programming (23 February - 6 March)**
Scientific Director: Prof. C. A. R. Hoare (Oxford, visiting at UT Austin)

The first YoP institute was devoted to one of computing's most active subject areas—the formal description of concurrent computations. Since it was YoP's first major event, it was fortunate that its scientific director was a member of the YoP executive committee and was in residence at UT during all the preparations for it.

The institute's first week began with a one-day presentation by INMOS Corporation on their Transputer, a processor intended as a building block for multiprocessor systems. It continued with a four-day tutorial on Communicating Sequential Processes (CSP), a notation and methodology for programming concurrent computations developed by the institute's director.

The second week began with a three-day Research Seminar, at which ten of the field's leading scientists presented some of their latest work. Jayadev Misra and K. Mani Chandy, of UT-Austin, presented their new methodology for concurrent programming based on iterated assignments; David May, of INMOS Ltd., described an integrated-circuit manufacturer's use of formal methods; James Woodcock and He Jifeng, from Oxford University, presented several applications and extensions of CSP; Charles Seitz, of CalTech, described the architecture, design, and programming of concurrent message-passing systems; Alain Martin, also of CalTech,

showed how concurrent-programming methodology can be used in the specification of VLSI circuits; Amir Pnueli, of the Weizmann Institute, presented some recent results in reasoning about concurrent systems using temporal logic; and Leslie Lamport, of Digital Equipment Corporation, lectured on the relationship between formal and informal methods and led, inspired, and moderated the discussion sessions that ended each day.

During the institute's final two days, the director and speakers were joined by a few invited observers to discuss their impressions of the preceding days and the institute's implications for the future of the discipline.

Four of the research seminar speakers presented evening lectures that were open to the public at no charge. Woodcock described the use of formal methods in software development at IBM's UK Laboratories, Lamport lectured on reasoning about concurrent programs, May described INMOS's formal verification of the floating-point-division section of a Transputer chip, and Seitz lectured on the effect on parallel architecture of the advent of VLSI technology.

2. **Encapsulation, Modularization, and Reusability (1-10 April)**
Scientific Director: Prof. David Gries (Cornell)

The second institute addressed methods for dealing with the problems attending large software systems by constructing them of well-structured and reusable software components. It began with a four-day tutorial intended to bring the audience up to date on such topics as data abstraction, polymorphism, encapsulation, and modular programming, drawing on experience with such programming languages as Modula-2, Cedar/Mesa, Ada, and SmallTalk. The tutorial speakers were (in addition to Prof. Gries) Jurg Gutknecht (ETH Zürich), C. A. R. Hoare (Oxford, visiting at UT Austin), James Donahue (Olivetti Research Center), Gregory Andrews (Arizona), Alan Snyder (Hewlett-Packard), and Luca Cardelli (Digital Equipment Corporation).

Following the pattern of the previous institute, the tutorial was succeeded by a three-day Research Seminar. John Mitchell (Bell Labs) described the addition of modules to the programming language ML, and showed how modules and polymorphism can interfere with each other. Cliff Jones (Manchester) and He Jifeng (Oxford) both presented work on data types and data refinement; Prof. Jones showed how these ideas appear in the context of the Vienna Definition Method, whereas Dr. He explored the relationship between prespecification and simulation in data refinement. John Guttag (MIT) presented LARCH, a language for writing well-structured specifications. Jan Prins (Wisconsin) presented recent work (with Prof. Gries) on modules and encapsulation, and J. Donohue presented some new ideas on bringing object-oriented and procedural programming together. Finally, Edsger W. Dijkstra gave a presentation of "Batcher's Baffler," a concurrent sorting algorithm.

The institute's final two days were devoted to a workshop attended by the speakers and a few invited observers. Most notable among the latter was Nax Mendler, a student of Robert Constable's at Cornell, who was invited on one day's notice when it was realized that his doctoral research, which was then practically complete, showed how two complementary approaches to encapsulation (one based on type theory and the other on proof theory) that had emerged during the research seminar could be brought together. This incident is offered as evidence that the Year of Programming has produced just the kind of scientific ferment and excitement that it was designed to bring about.

3. Logical Foundations of Functional Programming (8-12 June)
Scientific Director: Dr. Gérard Huet (INRIA)

The third institute was shorter than either of its predecessors, lasting only a single week, but like them it offered both a tutorial and a research seminar. The tutorial, which was a three-day introduction to the French school of functional programming and type theory, was taught by Dr. Huet and his colleague Guy Cousineau (École Normale Supérieure, Paris). This was the first institute in which working computer systems were involved; a SUN workstation and video projector were used in the lecture hall for demonstrations of CAML software, and evening sessions on the UT campus gave institute attendants an opportunity to try their hand at CAML programming.

The week ended with a two-day research seminar on linear logic and constructive semantics. Jean-Yves Girard (Université Paris 7) gave two lectures on qualitative domains, coherent spaces, and linear logic, and in a third lecture presented his latest work on a geometry of interaction. Albert Meyer (MIT) presented a talk on computability, John Mitchell (Bell Labs) and André Scedrov (Pennsylvania) lectured on relationships between type theories, and Susumu Hayashi (Kyoto) dealt with program extraction. John Reynolds (Carnegie-Mellon) presented a demonstration that polymorphism is not set-theoretic.

4. Formal Specification and Verification of Hardware (8-17 July)
Scientific Directors: Michael J. C. Gordon (Cambridge) and Warren A. Hunt Jr.
(UT Austin)

The fourth institute departed from precedent in several ways. It had two directors, who organized the institute from opposite sides of the Atlantic, and it consisted almost exclusively of a tutorial. Moreover, it involved computer systems as an integral part of the institute, rather than as an optional adjunct, and it set a record for the volume of lecture notes provided to the participants.

The institute was billed as a practical introduction to hardware specification and verification using two substantially different systems for machine-checked formal proofs: the Boyer-Moore Theorem Prover and the HOL Proof Assistant for Higher-Order Logic. The mornings were spent on lectures, and the afternoons on practical sessions using the two verification systems running on SUN workstations. Lecturing on HOL were Dr. Gordon, Tom Melham, and John Herbert, all from Cambridge University. The Boyer-Moore system was presented by Dr. Hunt and Matt Kaufmann, both at UT-Austin, with a supplementary lecture on Boyer-Moore logic by J Moore (also at UT-Austin).

The tutorial began with a three-day introduction to formal logic and to the SUN workstations and Unix. The remaining week was spent on learning to use the two verification systems, ranging from simple examples of formal specification (e.g., adders, counters) to advanced examples of verification (including the verification of the FM8501 cpu).

The course-evaluation questionnaires filled out by the students in the course reinforced the YoP office's impression that the institute's dependence on computing systems was a substantial liability. To begin with, the available population of SUNs and terminals (even during the summer term) limited the enrollment to 30 (students worked in pairs). Ensuring that the HOL software would run properly on UT's SUN-3s was difficult, requiring substantial efforts over three months to find and install the proper version of Franz Lisp and a last-minute scramble to correct a hardware design problem. Although the verification software itself was reasonably robust, the SUN/Unix/Ethernet environment supporting them proved somewhat fragile, and the complexity of *emacs*, the Unix editor, proved troublesome.

Despite these difficulties, and thanks to the efforts of UT support staff and the cooperation of SUN Microsystems, Inc. in overcoming them, the students' evaluations of the institute were generally quite positive.

5. **Declarative Programming (24-29 August)**
Scientific Director: Prof. David A. Turner (Kent)

The fifth institute returned to the format of the third one, with a three-day tutorial followed by a two-and-a-half day research seminar, and optional practical sessions on the UT campus in the evenings. Although the tutorial was taught by five lecturers— Samson Abramsky (Imperial College London), Richard Bird (Oxford University), John Hughes (University of Glasgow), Simon Thompson (University of Kent) and Prof. Turner — the obvious danger of fragmentation was nicely averted by the efforts of the director, who called his fellow instructors together for a day-long meeting early in July and then followed up with extensive correspondence to ensure the tutorial's coherence.

The tutorial, which provided an introduction to lazy functional programming, consisted of lectures interspersed with programming sessions (conducted with pencil and paper) attended by the lecturers and several teaching assistants. Major topics included data types, polymorphism, recursion and induction, lists, domain theory, program synthesis, and several case studies.

At the research seminar, each of the tutorial speakers gave a presentation on his recent research. Abramsky showed how the standard theory of λ -calculus can be extended to fit lazy functional languages. Hughes described *backward* analysis of functional programs, a technique that complements conventional (*forward*) techniques for such purposes as strictness analysis. Turner gave an account of his KAOS project, which is aimed at constructing an operating system of communicating processes written entirely in a functional notation. Thompson presented a method for analyzing the input-output behavior of systems defined in terms of functions on streams, and Bird described a calculus for deriving efficient implementations of programs involving lists.

The tutorial speakers were joined for the research seminar by six other scientists. Robert Cartwright, of Rice University, lectured on exact real arithmetic, and Peter Buneman (Pennsylvania) spoke on functional programming and databases. John Backus (IBM) addressed the problems of higher-order functions, input/output, and persistent files in a strict (i.e., non-lazy) functional language. Keshav Pingali (Cornell) presented a new data-structuring mechanism ("I-structures") intended as an efficient functional implementation of large data structures. Joseph Goguen (SRI) showed how higher-order functions can in many respects be replaced by a generic module facility, and David MacQueen (Bell Labs) described how type systems for functional programming languages are evolving to meet the demands placed on them by large-scale programming.

This institute elicited particular enthusiasm among a group of UT graduate students, who circulated among themselves, and subsequently presented to the UT Department of Computer Sciences, a petition calling on the department "to make Functional Programming a more visible priority in the department... [through] recruitment of faculty engaged in research in the field [and] more formal contacts with private research and other departments...".

- (6) **Specification and Design** (cancelled).
Scientific Director: J. R. Abrial (Paris).

The sixth institute, scheduled for 14-25 September, had to be called off when, a week after the announced date for acceptance of applications, only a dozen applications had arrived. Although the cancellation was not widely publicized (the applicants were of course notified at once), the total number of applications received by 14 September was less than 20.

The reasons for the sparsity of the turnout will never be known with certainty, but better communications among the organizers would have helped considerably. Perhaps September, when the American fall semester has just gotten under way, is not a good time for a gathering as long as two weeks; moreover, the announcements, mailed in July, may have found many of their recipients on holiday. Another factor, pointed out by one of the would-be speakers, is that M. Abrial is less widely known than some of the other YoP directors; those who know his work hold it in the highest regard, but M. Abrial has published comparatively seldom, and even in Europe his name is not particularly well known.

6. **Formal Development of Programs and Proofs (26-30 October)**
Scientific Director: E. W. Dijkstra (Texas)

The final YoP institute is a week in the future as this is written. According to its director, "If the first [institutes] were for full orchestra, the last one may very well be for a chamber ensemble." The speakers "have been selected for their expertise in the judicious use of formal techniques and in the presentation and derivation of proofs and programs." Their presentations, which will occupy four and one half days, are offered as "intellectual recitals, to be listened to by way of mental preparation for the high-quality programming of the near future."

The speakers will be Roland Backhouse (Groningen), Wim Feijen (Eindhoven, visiting UT Austin), David Gries (Cornell), Alain Martin (CalTech), Joseph Morris (Glasgow), Martin Rem (Eindhoven), Jan van de Snepscheut (Groningen), and A. M. van Gasteren (Waalre, The Netherlands).

Following the public session, the speakers will gather for a workshop lasting a day and a half.

Statistical Summary

The attendees at the first five Programming Institutes (counting participation by a single person in two institutes as two participants) numbered 367; of these, 128 were graduate students and 8 were post-doctoral researchers. In addition, the number of scientists participating as lecturers and as scientific directors was 49.

Among the universities represented at the first five YoP institutes were the following (the number of attendees from each institute is also shown):

Brown	3	Maryland	3
CalTech	2	MIT	4
Carnegie-Mellon	6	Pennsylvania	6
Cornell	9	Stanford	2
Illinois	1	Wisconsin	3

The list of YoP invitees and the list of YoP attendees for the first five Institutes are appended to this report.

Conclusions and Acknowledgments

By far the most important factor contributing to YoP's success was the caliber of the scientists who participated as directors and lecturers. This was due partially to the advice and counsel of the three leaders of the executive subcommittee in YoP's formative stages, and to their efforts and influence in recruiting their colleagues, but most importantly to the persuasiveness and negotiating skills of Dr. Hamilton Richards, the Director of the Year of Programming. The task of recruitment was eased by the resources placed at YoP's disposal by its sponsors, which made it clear that YoP was intent on recruiting the very best and was prepared to pay accordingly.

The staff of the YoP office — S. K. Rhoads and her assistant A. M. Mota — deserve a great deal of credit for their understanding of UT's administrative structure and procedures, for their dedication to YoP's success over many a late evening and working weekend, and for their diligence in organizing their own efforts and those of many part-time employees and student helpers to take care of the innumerable details that make an institute a success.

Among the infrastructural factors contributing to YoP's success was the availability of electronic mail, specifically, the Internet access provided by the university's DEC-20 and VAX/Unix computers. Without such a facility, cooperation among such geographically diverse groups on such tight schedules would have been impossible (though hardly conclusive, it is worth noting that the director of the cancelled sixth institute was the only YoP director not resident in Austin who was not accessible by electronic mail).

Another important contribution was the trio of Macintosh computers provided by the Department of Computer Sciences. The Macintosh text-preparation and database-management software has played a crucial role in the work of organizing and presenting the institutes (not to mention that of reporting on them).

A major concern from the YoP's early days was publicity — how to advertise the institutes to their potential audiences. An advertisement placed in the January 1987 issue of *Communications of the ACM* drew a disappointingly small response, no doubt partly because by the time it had to be submitted (in November), plans were still rather vague. Despite the small explicit response, however, the ad may well have prepared the CACM readership for the direct-mail and electronic bulletin-board campaigns that succeeded it.

Direct-mail advertising relied on the YoP mailing list, which has grown to 1700 names (500 with electronic-net addresses). Every institute announcement was distributed both by post and electronically; although a comprehensive analysis of results remains undone, our

impression is that the applications received were about evenly divided between postal and electronic mail. The large number of applications received from people not on our mailing list shows that announcements' original recipients were conscientious in distributing them to colleagues.

An unexpectedly minor source of applications was the ARPAnet bulletin board. The disappointing response is explained in part by the moderator's refusal to allow the posting of complete announcements (despite the YoP's military sponsorship, all mention of fees was rigorously prohibited), and by the long delay (often exceeding a month) between an announcement's posting and its appearance.

No doubt the number of applications would have been considerably higher had we been able to advertise in conventional journals and technical magazines, but the lead time for conventional advertising is simply far too long for events which remain in a state of becoming organized down to the final days. Had the YoP been spread out over three or four years, such conventional approaches might have been valid, but since most of the institutes were practically full (up to limits of available space and other facilities), the main practical effect of such advertising would have been to increase the number of rejected applications (which was in fact approximately zero).

Activities for 1987-88

Most of the remaining effort on the Year of Programming will be directed towards publication of the Institutes' proceedings, both in traditional textual form and as videotapes, and towards vigorous development of continuing education programs using this material.

The textual proceedings are to be published in six volumes—one per institute—each edited by its institute's scientific director. Addison-Wesley Publishing Company has been selected to publish the series, and final agreement awaits only UT's approval. Several manuscripts have been received, the majority in machine-readable form. The current plan is for each volume editor to select the papers for his volume and to advise authors on matters of technical content and general style. The YoP office will be responsible for editing all manuscripts into a uniform format and typographic style, and for translating into LaTeX manuscripts that are submitted as hard copy or other non-LaTeX forms.

Current plans for publishing the videotapes call for a joint venture between UT and MPA Inc., an established Austin media services firm which performed the original taping of the lectures and proposes to contribute sufficient editing to produce technically clean documentaries from the raw tapes. The resulting tapes will be offered for purchase both as individual lectures and as complete Institute sets.

APPENDIX A

List of Invitees and Attendees

UT Year of Programming Institutes

UT Year of Programming **List of Invitees**

Dr. Samson Abramsky	Imperial College London	5s
Prof. Gregory Andrews	University of Arizona: Computer Science	2s
Mr. John Backus	IBM	5s
Dr. Richard S. Bird	Oxford University	5s
Dr. Peter Buneman	University of Pennsylvania	5s
Dr. Luca Cardelli	DEC Systems Research Center	2s
Dr. Robert C. Cartwright	Rice University	5s
Prof. K. Mani Chandy	UT Austin: Computer Sciences	1s
Prof. Guy Cousineau	Ecole Normale Supérieure	3s
Prof. dr. Edsger W. Dijkstra	UT Austin: Computer Sciences	1o
Dr. Jim Donahue	Olivetti Research Center	2s
Prof. Jean-Yves Girard	Université Paris 7	3s
Dr. Joseph A. Goguen	SRI International	5s
Dr. Michael J. C. Gordon	University of Cambridge: Computer Lab.	4d
Prof. Mohamed G. Gouda	UT Austin: Computer Sciences	1o
Prof. David Gries	Cornell University: Computer Science	2d
Dr. Jurg Gutknecht	ETH Zürich: Institut für Informatik	2s
Prof. John Guttag	M.I.T. Lab for Computer Science	2s
Prof. Susumu Hayashi	Kyoto University	3s
Dr. Jifeng He	Oxford University: Computing Laboratory	1s,2s
Prof. E. C. R. Hehner	University of Toronto: Computer Science	2o
Dr. John Herbert	University of Cambridge: Computer Lab.	4s
Mr. Stephen Hill	University of Kent	5t
Prof. C. A. R. Hoare	UT Austin: Computer Sciences	1d
Mr. Gareth Howells	University of Kent	5t
Dr. Gérard Huet	INRIA	3d
Prof. R J M Hughes	Glasgow University	5s
Dr. Warren A. Hunt Jr.	Computational Logic, Inc.	4d
Prof. Cliff Jones	The University, Manchester: Computer Science	2s
Dr. Matt Kaufmann	Institute for Computing Science...	4s
Dr. Leslie Lamport	Digital Equipment Corp.-SRC	1s
Dr. David B. MacQueen	AT&T Bell Laboratories	5s
Prof. Alain J. Martin	California Institute of Technology	1s
Dr. David May	INMOS, Ltd.	1s
Mr. Thomas F. Melham	University of Cambridge: Computer Lab.	4s
Mr. Nax Mendler	Cornell University	2w
Prof. Albert R. Meyer	MIT Laboratory for Computer Science	3s
Prof. Jayadev Misra	UT Austin: Computer Sciences	1s
Dr. John Mitchell	Bell Laboratories	2s
Dr. J Strother Moore	Computational Logic, Inc.	4s
Prof. Ernst-Rüdiger Olderog	University of Kiel	1s
Prof. Keshav K. Pingali	Cornell University	5s
Prof. Gordon Plotkin	University of Edinburgh	1o
Prof. Amir Pnueli	Weizmann Institute	1s
Mr. Jan Prins	University of Wisconsin/Madison: Comp. Sci.	2s
Prof. John Reynolds	Carnegie-Mellon University	3s
Prof. André Scedrov	University of Pennsylvania	3s
Prof. Fred B. Schneider	Cornell University	1o
Prof. Charles L. Seitz	California Institute of Technology	1s
Dr. Alan Snyder	Hewlett Packard Labs	2s
Dr. Robert E. Strom	IBM T. J. Watson Research Center	1o

UT Year of Programming
List of Invitees

Dr. Simon J. Thompson	University of Kent	5s
Prof. David A. Turner	University of Kent	5d
Prof. Jan L. A. van de Snepscheut	Rijksuniversiteit Groningen	1o
Prof. Peter Wegner	Brown University: Computer Science	2o
Dr. John Williams	IBM Almaden Research Center	2o
Mr. Edward L. Wimmers	IBM	5o
Dr. Pierre Wolper	Universite de Liege	1o
Dr. Jim Woodcock	Oxford University: Computing Laboratory	1s

*Legend: 5s denotes 5th institute speaker.

s - speaker
d - director
o - observer
t - teaching assistant
w - workshop participant only

University of Texas
Year of Programming

Institute of Concurrent Programming
Austin, Texas

23 February - 6 March 1987



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